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Relationship between Movement Quality, Functional Ambulation Status, and Spatiotemporal Gait Parameters in Children with Myelomeningocele.

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Title: Relationship between movement quality, functional ambulation status, and spatiotemporal gait parameters in children with myelomeningocele

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Abstract

Aims: We investigated relationships among the Pediatric Neuromuscular Recovery Scale (Peds NRS), modified Hoffer Scale, and spatiotemporal gait parameters in children with myelomeningocele (MMC).

Methods: 21 children with MMC, age 5.3 years (SD = 2.6), were assessed by three clinicians using the Peds NRS and modified Hoffer Scale. In eight children, gait parameters were also measured.

Results: The Peds NRS summary score demonstrated good correlation with modified Hoffer Scale score ($r = -0.64$, $p = 0.002$) that accounted for 41% of variation in summary score. Six Peds NRS seated/standing items exhibited good relationships with modified Hoffer Scale ($r = -0.51$ to -0.70, $p \leq 0.023$), and the sit-to-stand item demonstrated an excellent relationship ($r = -0.85$, $p<0.001$). Sit-to-stand and three standing/walking items exhibited excellent associations with cadence ($R_s = 0.81$ to 0.88, $p \leq 0.014$), and swing and stance time (both $R_s = -0.83$ to -0.90, $p \leq 0.01$). Two Peds NRS standing items and modified Hoffer Scale score demonstrated good correlations with velocity ($R_s = 0.71$, $p= 0.047$; $R_s = -0.73$, $p= 0.04$, respectively).

Conclusions: Our findings suggest that children with MMC who exhibit greater movement quality and trunk control are likely to be functional ambulators with more optimal spatiotemporal gait parameters.

The prevalence of spina bifida among children in the United States is estimated to be about 0.3 per 1,000 births and 1.9 per 1,000 births worldwide (Shin et al., 2010; Sawin et al., 2015, Smith & Krynska, 2015). This condition is caused by a failure of the neural tube to close during the early stages of gestation. Myelomeningocele (MMC), the most common and severe form of spina bifida, results in damage to the spinal cord and nerves at, below, or above the level of the lesion. MMC is often accompanied by Chiari II malformation causing hydrocephalus and hydromyelia (Tsai, Yang, Chan, Huang, & Wong, 2002). Children with MMC are born with a range of life-long impairments, which may include muscle weakness, loss of sensation, poor coordination, decreased balance, cognitive dysfunction, and bowel and bladder incontinence (Steinhart et al., 2016). The combination of these impairments results in an overall decrease in functional mobility and participation.

Several outcome measures have been used by physical therapists (PT) and occupational therapists (OT) to evaluate gross motor function in children with MMC. Questionnaires such as the Pediatric Evaluation of Disability Inventory or the Functional Mobility Scale rely on parent observation or opinion about the child's functional abilities (Schoenmakers, Uiterwaal, Gulmans, Gooskens, & Helders, 2005; Bisaro, Bidonde, Kane, Bergsma, & Musselman, 2015). Other assessments, such as the Gross Motor Function Measure and Functional Independence Measure for Children utilize clinical observation of functional movements (Russell et al., 2000; Josenby, Jarnlo, Gummesson, & Nordmark, 2009; Ottenbacher et al., 2008). Bartonek, Eriksson, and Saraste (2001) developed Muscle Function Classes based upon lower extremity muscle strength, which have been shown to correlate to different levels of ambulation (Bartonek & Saraste, 2001; Bartonek, 2010). While all these tests rate the achievement of functional movements for children with neurological conditions, they do not assess the quality with which the child performs the movements. To our knowledge, the validity and reliability of these measures in assessing children with MMC have not been reported (Bisaro et al., 2015; Josenby et al., 2009; Ottenbacher et al., 2008, Bartonek & Saraste, 2001; Bartonek, 2010).

Assessing the quality of gross motor movements in infants is an important aspect to identifying children at high risk for developmental disorders. The quality of a child's movement provides insight into the functioning of the central nervous system (Hadders-Algra, 2004). In children with neuromotor disorders, the assessment of movement quality provides an understanding of the child's efficiency of movement, risk of developing secondary impairments, and level of safety when performing functional tasks (Sorsdahl et al, 2010).

The Pediatric Neuromuscular Recovery Scale (Peds NRS) is a valid and reliable measure that assesses quality of functional movement in children with spinal cord injury (Ardolino et al., 2016; Behrman et al., 2019), and children with MMC ages one to 12 years (Ardolino, Flores, Ferreira, Nickelson Jeantete, & Manella, 2019). The Peds NRS assesses lower level function such as trunk control during sitting balance, as well as higher level function such as amount of support needed for standing and walking. In addition, this scale also measures upper extremity function that may be impacted by Chiari II malformation in children with MMC (Ardolino et al., 2016; Behrman et al., 2019).

In ambulatory children, outcome measures such as the 6-minute walk test, 2-minute walk test, and Timed 'Up and Go' are often employed to assess walking function in children with spina bifida (Bisaro et al., 2015; de Groot et al., 2011; Kane, Lanovaz, Bisaro, Oates, & Musselman, 2016). Perhaps the most commonly used assessment to classify the ambulatory status of children with spina bifida is the Hoffer Functional Ambulation Scale (Hoffer Scale) (Bartonek & Saraste, 2001; Hoffer, Feiwell, R. Perry, J. Perry, & Bonnet,1973). The original

Hoffer scale ascertains the child's ambulatory status using only four categories and therefore may have decreased responsiveness and discriminative validity, however the modified Hoffer Scale includes five categories (Bisaro et al., 2015; Hoffer et al.,1973; Bartonek & Saraste, 2001). In a recent systematic review of walking measures for children with spina bifida, Bisaro et al. (2015) suggested that the modified Hoffer Scale be used in research and clinical practice to consistently classify walking function in children with spina bifida. As this outcome measure does not assess quality of walking function, there is a need to augment it with a measure of quality of gait.

Several studies have investigated gait kinematics in children with MMC. In children with lumbosacral level MMC, characteristic gait deviations include crouch gait (excessive lower limb flexion), and increased pelvic anterior tilt, rotation and obliquity (Vankoski, Sarwark, Moore, & Dias,1995; Duffy, Hill, Cosgrove, Corry, & Graham, 1996a; Bartonek & Saraste, 2001; Fabry, Molenaers, Desloovere, & Eyssen, 2000; Gutierrez, Bartonek, Haglund-Akerlind, & Saraste, 2005; Kane & Barden, 2010). Altered gait mechanics contribute to increased energy costs, impaired balance, and mobility restrictions (Bartonek & Saraste, 2001; Duffy et al., 1996b). Characteristic gait patterns in the upper and lower body emerge with successive weakness in lower limb muscle groups (Gutierrez, Bartonek, Haglund-Akerlind, & Saraste, 2003a). While several studies have investigated the gait kinematics of this population, few studies have explored the spatiotemporal gait parameters in children with MMC. Gait velocity at self-selected walking speed and stride length are the most frequently reported spatiotemporal gait parameters (Ivanyi et al., 2015). Gutierrez et al. (2003a) illustrated that hip extensor strength strongly influences gait velocity in ambulatory children with lumbosacral MMC. However, to our knowledge, no studies have investigated the influence of postural control on spatiotemporal gait parameters in this population.

The purpose of this exploratory study was three-fold, to investigate the relationships between 1) movement quality (Peds NRS) and functional ambulation status (Modified Hoffer), 2) movement quality (Ped NRS) and spatiotemporal gait parameters, and 3) functional ambulation status (Modified Hoffer) and spatiotemporal gait parameters in children with MMC. We hypothesized good associations between 1) Peds NRS scores and Modified Hoffer score, 2) Peds NRS scores and spatiotemporal gait parameters, and 3) Modified Hoffer and spatiotemporal gait parameters. We further hypothesized that the Modified Hoffer is a significant predictor of Peds NRS score.

Methods

Participants

A priori power analysis using G*Power[1] for a Pearson correlation test with a large effect size of $\rho = 0.7$, power = 0.9 and $p = 0.05$ revealed a sample size of 14 participants was required for this study (Portney & Watkins, 2009). For linear regression with an effect size of $f^2 = 0.7$, power = 0.9, and $p = 0.05$, a sample size of 18 participants was required. Therefore, 21 participants (10 female, 11 male) with MMC were recruited from local parent support groups and outpatient clinics. The average age of the participants was 5.3 years old (SD = 2.6). Descriptive statistics for each variable are found in Table 1.

Inclusion criteria for participation in the study were: (1) ages one through 12 years old (2) diagnosis of MMC; (3) physician clearance; and (4) medically stable and with no restrictions for lower extremity weight bearing. Participants were excluded if they had: (1) a history of lower

[1] G*Power Version 3.1.9.2, Franz Faul, Universitat Kiel, Germany

extremity fracture; (2) trunk or lower extremity muscle contractures that limited standing; (3) severe scoliosis that required surgery; or (4) a medical reason that contraindicated standing. This study was approved by the Institutional Review Board of [redacted]. Informed consent of each parent and child was obtained prior to participation in the study.

Measures

The Peds NRS is an outcome measure used to assess quality of movement in children with spinal cord injuries or MMC (Ardolino et al., 2016; Ardolino et al., 2019). Content validity was determined through Delphi methodology in which consensus was obtained from a group of experts (Ardolino et al., 2016). Reliability for the Peds NRS has been found to be good to excellent (ICC $\geq$ 0.80) for individual items and overall score (Ardolino et al., 2019). The test is comprised of 13 items divided into four subsections: sitting, upper extremity function, standing, and walking. To administer the Peds NRS, a height-adjustable bench, a mat table, various fine-motor manipulatives, and a ball are needed. Standing and walking items may require extra personnel to administer.

The Peds NRS is divided into three age groups: one to two-years-old, three to five-years-old, and six to 12-years-old. Appropriate verbal cues and scoring guidelines are provided for each age group (Ardolino et al., 2016). Each of the 13 items on the Peds NRS is scored on a 12-point scale, with one point allocated to each of 12 phases of the item. On the item card, the therapist is instructed to begin at a designated “start phase” indicated by a bold box around one of the 12 phases. If the child cannot perform the movement as listed in that phase, the therapist backtracks and starts at the beginning of the item card to assess the child’s performance at the first phase. The therapist continues sequentially through the phases on the item card until the child is unable to perform one of the phases. The therapist then scores the highest phase achieved by the child and moves on to the next item card, through all 13 items. A summary Peds NRS score is obtained through an algorithm using the sum of the items. The Peds NRS is a valid and reliable measure of movement quality (Ardolino 2016, Ardolino 2019, Behrman 2019).

The modified Hoffer Scale uses five levels to classify the ambulatory status of children with MMC with the lowest score (level 1) representing the highest functional walking ability (Table 2) (Bisaro et al., 2015). The tool requires no training and no effort on the part of the child. The classification level is determined through parent and child verbal report of the child's ambulatory status at home and in the community. Convergent validity on the original Hoffer scale has been established (Pauly & Cremer, 2013; Bisaro et al., 2015). Evidence indicates the Hoffer scale is reliable in patients with spinal cord injury, with 85.7% agreement and a weighted kappa of 0.74 (Nachtegaal, van Langeveld, Slootman, & Post, 2018).

The Zeno™ Walkway[2] is a three-foot-wide by 18-foot-long pressure-sensing mat used to measure spatiotemporal gait parameters. Evidence of concurrent and construct validity have been found to support the use of the Zeno™ Walkway (Vallabhajosula, Humphrey, Cook, & Freund, 2019; Berg-Poppe, Cesar, Tao, Johnson, & Landry). Reliability of the Zeno™ Walkway is good, with ICC ≥ 0.84 for all measured parameters (Egerton, Thingstad, & Helbostad, 2014). As a child walks down the length of the mat, values are generated for gait velocity (centimeters per second), cadence (steps per minute), stride width (centimeters), stance phase (% of gait cycle), and swing phase (% of gait cycle).

Procedure

[2] ProtoKinetics, Havertown, Pennsylvania

Children were classified on the modified Hoffer Scale through verbal questions of both the caregiver and the child to determine the child's typical ambulatory status. Two PTs and two OTs with at least two years of pediatric experience were trained in the administration and scoring of the Peds NRS. Each child received a summary score for the Peds NRS by three different examiners (two PTs and one OT) through two live testing sessions and one video recorded session. The live testing sessions were performed two weeks apart and the video recording of one of these sessions was used by the third examiner to score the child. Thus, every child was scored by two PTs and one OT, who were all blinded to each other's scores and administration procedures. The procedure for administering the Peds NRS is explained in detail elsewhere (Ardolino et al., 2016).

Gait parameters were obtained on a subsample of eight children using the Zeno™ Walkway. The Zeno™ Walkway was not available when the study was initiated, therefore only the last eight ambulatory children were able to be tested on their gait parameters. Children wore their orthotics and used their assistive devices if needed. They were allowed one practice walk and data was collected on the second walk down the length of the mat.

Data Analysis

Data was analyzed using IBM SPSS Statistics 25 software.[3] The mean score of each item of the Peds NRS was calculated, as well as the mean summary score. To examine the relationship between the modified Hoffer Scale and the Peds NRS, a Pearson correlation was calculated for the mean score of each item and the mean summary score. A p-value < 0.05 was used to indicate significance. Pearson correlation results were interpreted as: poor (0 to 0.25), fair (>0.25 to 0.50), good (>0.50 to 0.75), and excellent (>0.75). (Portney & Watkins, 2009)

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[3] IBM Corporation, Armonk, New York

To explore whether the modified Hoffer Scale score has a predictive effect on the Peds NRS summary score in children with MMC, a linear regression model was used:

$$(\text{Peds NRS})_i = b_0 + b_1(\text{Modified Hoffer})_i$$

To investigate the association of spatiotemporal gait parameters to Peds NRS score and modified Hoffer Scale score, a Spearman's Rho correlation was calculated for the eight children who participated in the Zeno^{TM} Walkway data collection. Variables included the spatiotemporal gait parameters (velocity, cadence, stride width, stance phase, and swing phase), modified Hoffer Scale score, mean of each item on the Peds NRS, and Peds NRS summary score.

Results

Twenty-one children with MMC (10 female, 11 male) participated in the study. The youngest child was 1.5 years old and the oldest was 10 years old (mean = 5.3 years, SD = 2.6). Children varied in their use of assistive devices and orthotics. Modified Hoffer scale scores ranged from one to five; however, none of the children scored a three on the scale. Descriptive statistics for the variables are found in Table 1. The overall mean score of the Peds NRS was 8.60 (SD = 2.31). The mean scores for spatiotemporal characteristics of the eight participants who were measured on the Zeno^{TM} Walkway were: velocity = 76.40cm/sec (SD = 25.48), cadence = 125.29steps/min (SD = 54.19), stride width = 13.89cm (SD = 3.97), stance time = 65.68% of gait cycle (SD = 4.22), swing time = 34.32% of gait cycle(SD = 4.22).

Pearson correlation values for the average score of each Peds NRS item and the modified Hoffer Scale are presented in Table 3. The relationship between the Peds NRS items and the modified Hoffer Scale was fair for all upper extremity items, however, none reached significance; and good for six items (supine to sit, sit inside base of support (BOS), sit outside BOS, static stand, dynamic stand, and walk), (r = -0.506 to -0.697, $p \leq 0.023$). Sit to stand was the only item to demonstrate an excellent relationship with the Modified Hoffer Scale (r = -0.845, p < 0.001). The Peds NRS mean summary score was calculated as 8.60 (SD = 2.31) and exhibited a good correlation with the modified Hoffer Scale score (r = -0.64, p = 0.002).

Linear regression was performed to determine if modified Hoffer Scale score predicted Peds NRS summary score. A significant regression equation was found, $R = 0.64$, $R^2 = 0.41$, $F(1,19) = 13.182$, $p = 0.002$. The modified Hoffer Scale score accounted for 41% of the variation in Peds NRS summary score. The raw coefficients for the predictive equation were as follows:

$$\text{Peds NRS} = 11.23 - 0.0971(\text{Modified Hoffer})_i$$

Spearman's Rho correlations of spatiotemporal gait parameters with Peds NRS scores and modified Hoffer score in the eight children who participated in the Zeno™ Walkway data collection are presented in Table 4. There was no significant correlation between Peds NRS summary score and spatiotemporal gait parameters. Peds NRS item 3, sitting outside BOS, exhibited a good correlation with stride width (R_s = -0.733, p = 0.039) and a moderate association with velocity that approached significance (R_s = 0.655, p = 0.078). Peds NRS items 10 (sit to stand), 11 (static standing), 12 (dynamic standing), and 13 (walking) exhibited excellent associations with cadence (R_s = 0.814 to 0.881, $p \leq 0.014$), swing time (R_s = 0.833 to 0.898, $p \leq 0.010$), and stance time (R_s = -0.833 to -0.898, $p \leq 0.010$). In addition, Peds NRS items 11 (static standing) and 12 (dynamic standing) demonstrated good correlations with velocity (R_s = 0.714, p = 0.047) while items 10 (sit to stand) and 13 (walking) exhibited good correlations with velocity that approached significance (R_s = 0.659 to 0.683, $p \leq 0.076$). The modified Hoffer Scale score demonstrated a good association with velocity (R_s = -0.730, p = 0.040).

Discussion

To our knowledge, this is the first study to examine the relationship between movement quality, functional ambulation status, and spatiotemporal gait parameters in children with MMC. Given the sample size, this exploratory study only established initial evidence of these relationships.

Relationship between movement quality and functional ambulation status

The Peds NRS seated items (supine to sit, sit inside BOS and sit outside BOS) assess segmental trunk control and demonstrated good, negative correlations with the modified Hoffer Scale score. This indicates that trunk control may influence functional ambulation status. In general, children with higher scores on these Peds NRS items were able to ambulate in their homes and communities. On the seated items, to obtain a score of 10 or above (Table 3), children must be able to maintain appropriate sitting posture with stabilization at only the pelvis, or without any stabilization. The good association of these items with the modified Hoffer Scale score suggests that they were more functional ambulators. On the standing items (sit to stand, static standing, dynamic standing and walking), to achieve the mean scores observed in Table 3, children must be able to maintain appropriate trunk kinematics in a standing position with assist at only the pelvis and lower extremities. This relationship between trunk control in standing and functional ambulation is observed through good to excellent correlations of these items and modified Hoffer scale score. Children who only needed support at the pelvis or lower extremities on these items were more likely to be functional ambulators. This concurs with the findings of Curtis et al. (2015) and Montero Mendoza et al. (2015), who concluded that trunk control was a significant factor in predicting gross motor function and ambulation in children with CP. In both of these studies, children who could maintain postural control in sitting with only pelvic support were more likely to have higher scores on the GMFM (Curtis et al., 2015) or ambulate with an assistive device (Montero Mendoza et al., 2015). In addition, the present study found that sit-to-stand was the most highly correlated item with the modified Hoffer Scale score, indicating that better hip extensor control also relates to a higher level of functional ambulation.

Relationship between movement quality and gait parameters

The relationship between trunk control and a child's ability to ambulate is further exemplified through the good correlations between the Peds NRS standing items (sit-to-stand, static standing, dynamic standing, and walking) and the spatiotemporal parameters of velocity, cadence, stance time and swing time. Children who approached more normative values of these four gait parameters tended to need minimal or no support at the pelvis and lower extremities, indicating good control of their upper trunk segments. Item 10 (sit-to-stand) is the Peds NRS item that explicitly assesses hip extensor activation. The excellent correlation of item 10 with cadence, swing time and stance time further supports the work of Gutierrez et al. (2003), who reported that children with active hip extension exhibited increased stride length and ambulation velocities.

Relationship between functional ambulation status and gait parameters

The only gait parameter that demonstrated a significant correlation with the modified Hoffer Scale score was gait velocity. This relationship is not surprising, given that children with faster velocities exhibit a higher level of functional ambulation (Bartonek et al. 2001, Bartonek et al., 2002). The children in our study who were community ambulators (modified Hoffer Scale score of 1 or 2) had walking speeds that ranged from 0.66 m/s to 0.95 m/s. These speeds are slightly lower than those found by Bartonek et al. (2002), who reported gait velocities ranging from 0.72 – 1.17 m/s in four children with MMC who were community ambulators, and velocities ranging from 0.48 - 0.9 m/s in four children with MMC who were household ambulators (Bartonek et al., 2002). However, the children in our study were younger (mean age of 5 years compared to 10 years in the Bartonek et al., 2002 article) and used assistive devices to ambulate as compared to those tested by Bartonek et al. (2002) who did not use assistive devices. The lack of significant correlations between the other gait parameters and the modified Hoffer Scale score indicate that the modified Hoffer Scale does not inform the clinician about the quality of a child's walking function.

Clinical Implications

The results of the relationships studied in this investigation indicate the importance of assessing quality of movement and segmental trunk control in children with MMC. The findings show that children who have segmental control of the upper and lower trunk, and who may only need support at the pelvis in both sitting and standing have a greater likelihood of being functional ambulators and more optimal spatiotemporal gait parameters.

The number of good to excellent correlations between Peds NRS items and the summary score, the modified Hoffer Scale, and spatiotemporal gait parameters supports the concurrent validity of the Peds NRS in this population. The association between the Peds NRS and modified Hoffer Scale is strengthened by the regression finding that the Modified Hoffer Scale score explains 41% of the variation in Peds NRS summary score. This evidence indicates functional ambulation status moderately related to quality of movement in children with MMC. Additionally, knowing a child's modified Hoffer Scale score allows the clinician to prepare appropriately for administering the Peds NRS with that child, with regards to the number of personnel who may be needed to assist with the testing.

Study Limitations

While our study was adequately powered for the regression analysis, we were able to test spatiotemporal gait parameters in only eight of the 21 children with the Zeno walkway system. We hypothesize that we may have seen more significant correlations between the gait parameters and the other scales had we been able to test a larger sample size of children. However, the subsample of eight children tested was diverse in age and use of assistive devices and orthoses.

We were unable to ascertain a reliable neurological lesion level for each participant as we did not have access to each child's medical records. However, this study focused on the quality of functional movement and ambulation status, and we obtained a diverse sample of functional abilities representative of this population.

Conclusion

The finding of concurrent validity, in conjunction with our previous findings of good interrater reliability (Ardolino et al., 2019), illustrate that the Peds NRS is a viable tool for clinicians to use to assess movement quality in children with MMC.

Declaration of interest:

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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Table 1. Descriptive statistics of the participants

Participant Number	Age (years)	Gender	Modified Hoffer Scale Score	Assistive Devices	Orthotics
1	9	M	2	B forearm crutches	B AFO
2	7	F	2	4w reverse RW	B AFO
3	8	M	1	None	B AFOs
4	6	F	2	4w reverse RW	B AFO
5	1.5	M	2	None	B AFOs
6	7	M	2	4w reverse RW	B KAFO
7	5	F	4	Standing frame	B AFO
8	4	F	2	Gait trainer	B KAFO
9	4	F	4	Gait trainer	B KAFO
10	6	M	5	Standing frame, cervical support	B AFO
11	5	F	1	None	None
12	2.5	F	2	None	None
13	4	M	1	None	B AFO
14	7	F	4	4w reverse RW	B HKAFO
15	10	F	2	B forearm crutches	B AFO
16	4	M	1	None	B AFO
17	3	M	4	4w reverse RW	B AFO
18	7	M	5	Gait trainer	B AFO
19	9	F	5	Standing frame	B KAFO
20	1.7	M	5	None	None
21	1.5	M	1	None	B AFO
Summary	Mean = 5.3 SD=2.6	11 M 10 F			

B = Bilateral, AFO = Ankle-Foot Orthosis, 4w = 4 Wheeled, RW = Rolling Walker, KAFO = Knee-Ankle-Foot Orthosis, HKAFO = Hip-Knee-Ankle-Foot Orthosis, SD = Standard Deviation

Table 2. Modified Hoffer Scale.

Modified Hoffer Level	**Description**
Level 1	Community ambulation
Level 2	Community ambulation with wheelchair use for long distances outdoors
Level 3	Household ambulation
Level 4	Household ambulation with wheelchair use indoors and outdoors
Level 5	Non-functional ambulation

Table 3. Correlation of Peds NRS items and summary score with modified Hoffer Scale score

Peds NRS Variable	Mean Score (SD)	*r*	*p*
Item 1 (Supine-to-Sit)	10.47 (2.41)	-0.506	0.023*
Item 2 (Sit – Inside Base of Support)	10.49 (2.80)	-0.545	0.011*
Item 3 (Sit – Outside Base of Support)	10.05 (3.20)	-0.573	0.007*
Item 4 (Object to Mouth- right)	11.27 (2.32)	-0.310	0.183
Item 5 (Object to Mouth- left)	11.32 (2.37)	-0.330	0.156
Item 6 (In-Hand Manipulation- right)	8.20 (3.97)	-0.286	0.281
Item 7 (In-Hand Manipulation- left)	7.90 (3.92)	-0.256	0.276
Item 8 (Reach Overhead- right)	10.34 (2.99)	-0.261	0.266
Item 9 (Reach Overhead- left)	10.68 (2.65)	-0.367	0.111
Item 10 (Sit-to-Stand)	7.06 (3.23)	-0.845	<0.001*
Item 11(Static Standing)	4.83 (3.15)	-0.697	<0.001*
Item 12 Dynamic Standing	4.65 (3.26)	-0.694	<0.001*
Item 13 Walking	5.24 (3.74)	-0.674	0.001*
Mean Summary Score (derived from algorithm)	8.60 (2.31)	-0.640	0.002*

r = Pearson Correlation Coefficient
*indicates significance at $p \leq 0.05$

Table 4. Relationship of Peds NRS items and summary score and modified Hoffer Scale score with spatiotemporal gait parameters (n = 8)

	Velocity (cm/sec)	Cadence (steps/min)	Stride Width (cm)	Stance Time (% of gait cycle)	Swing Time (% of gait cycle)
Peds NRS Summary Score	R_s = -0.252 p = 0.548	R_s = -0.287 p = 0.490	R_s = -347 p = 0.399	R_s = -0.060 p = 0.868	R_s = -0.060 p = 0.868
Item 1 (Supine-to-Sit)	R_s = -0.300 p = 0.470	R_s = -0.327 p = 0.429	R_s = -0.082 p = 0.847	R_s = 0.300 p = 0.470	R_s = -0.300 p = 0.470
Item 2 (Sit – Inside BOS)	R_s = 0.689 p = 0.689	R_s = -0.056 p = 0.895	R_s = -0.620 p = 0.101	R_s = 0.394 p = 0.334	R_s = -0.394 p = 0.334
Item 3 (Sit – Outside BOS)	R_s = 0.655 p = 0.078$^+$	R_s = 0.405 p = 0.319	R_s = -0.733 p = 0.039*	R_s = -0.016 p =0.971	R_s = 0.016 p = 0.971
Item 4 (Object to Mouth- R)	R_s = -0.577 p = 0.134	R_s = -0.577 p = 0.134	R_s = 0.082 p = 0.846	R_s = 0.577 p = 0.134	R_s = -0.577 p = 0.134
Item 5 (Object to Mouth- L)	R_s = -0.577 p = 0.134	R_s = -0.577 p = 0.134	R_s = 0.082 p = 0.846	R_s = 0.577 p = 0.134	R_s = -0.577 p = 0.134
Item 6 (In-Hand Manipulation- R)	R_s = -0.590 p = 0.900	R_s = -0.453 p = 0.307	R_s = 0.355 p = 0.435	R_s = 0.433 p = 0.331	R_s = -0.433 p = 0.331
Item 7 (In-Hand Manipulation- L)	R_s = 0.990 p = 0.834	R_s = -0.256 p = 0.579	R_s = 0.158 p = 0.736	R_s = 0.315 p = 0.491	R_s = -0.315 p = 0.491
Item 8 (Reach Overhead- right)	R_s = -0.134 p = 0.775	R_s = -0.089 p = 0.849	R_s = -0.089 p = 0.849	R_s = -0.178 p = 0.702	R_s = 0.178 p = 0.702
Item 9 (Reach Overhead- left)	R_s = 0.134 p = 0.775	R_s = -0.089 p = 0.849	R_s = -0.223 p = 0.631	R_s = -0.134 p = 0.775	R_s = 0.134 p = 0.775
Item 10 (Sit-to-Stand)	R_s = 0.683 p = 0.062$^+$	R_s = 0.814 p = 0.014*	R_s = -0.563 p = 0.146	R_s = -0.874 p = 0.005*	R_s = 0.874 p = 0.005*
Item 11(Static Standing)	R_s = 0.714 p = 0.047*	R_s = 0.881 p = 0.004*	R_s = -0.643 p = 0.086$^+$	R_s = -0.833 p = 0.010*	R_s = 0.833 p =0.010*
Item 12 Dynamic Standing	R_s = 0.714 p = 0.047*	R_s = 0.881 p = 0.004*	R_s = -0.643 p = 0.086$^+$	R_s = -0.833 p = 0.010*	R_s = 0.833 p = 0.010*
Item 13 Walking	R_s = 0.659 p = 0.076$^+$	R_s = 0.850 p = 0.007*	R_s = -0.491 p = 0.217	R_s = -0.898 p = 0.002*	R_s = 0.898 p = 0.002*
Modified Hoffer Scale Score	R_s = -0.730 p = 0.040*	R_s = -0.587 p = 0.126	R_s = 0.222 p = 0.598	R_s = 0.391 p = 0.398	R_s = -0.391 p = 0.398

BOS = Base of Support

R_s = Spearman's Rho correlation

*indicates significance at $p \leq 0.05$

$^+$indicates approaching significance at $p \leq 0.1$